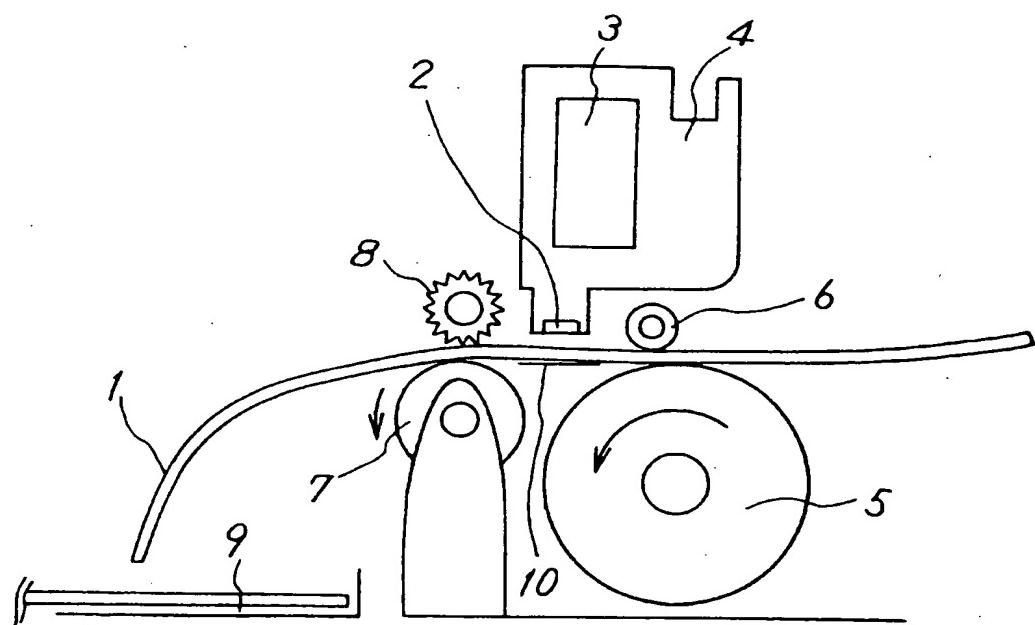
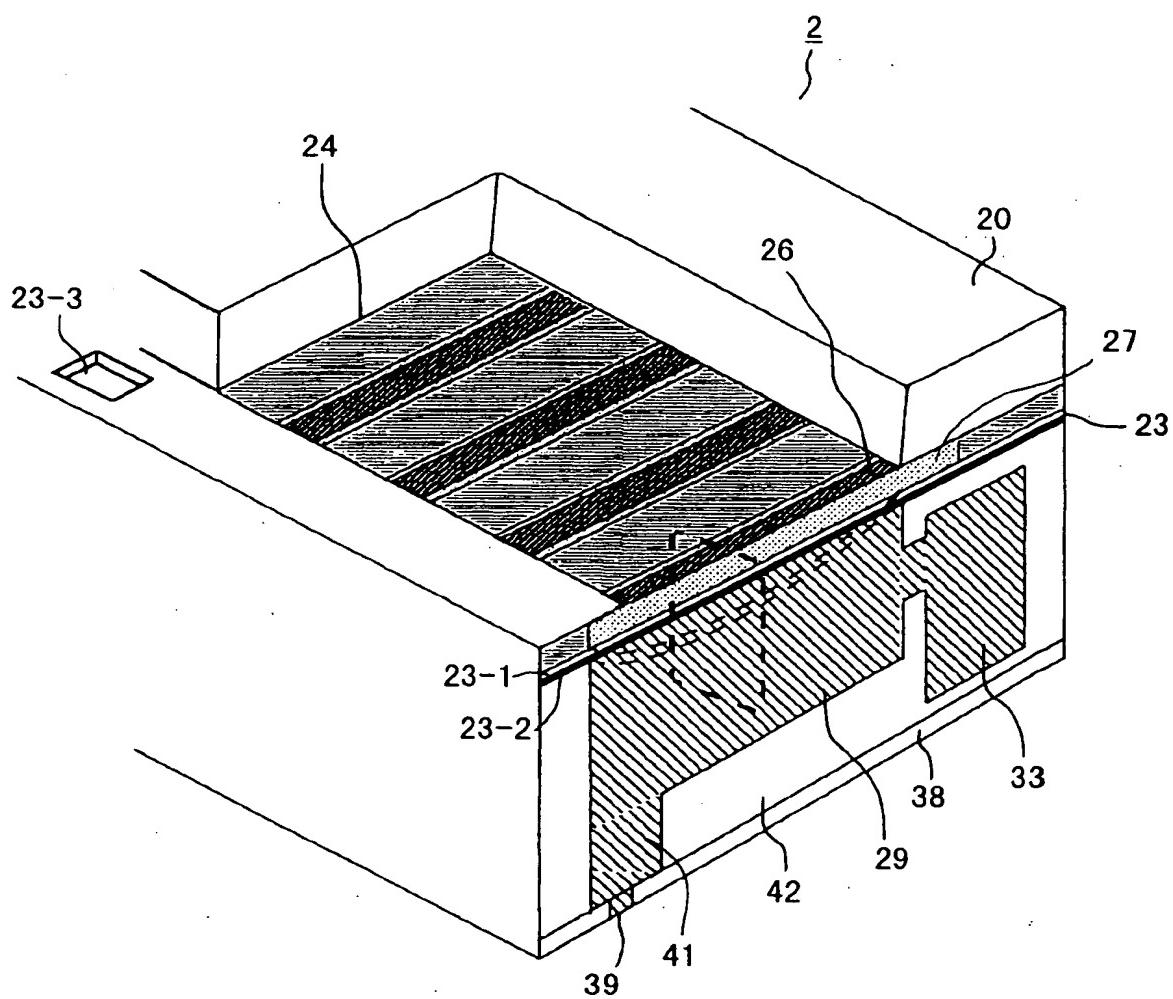


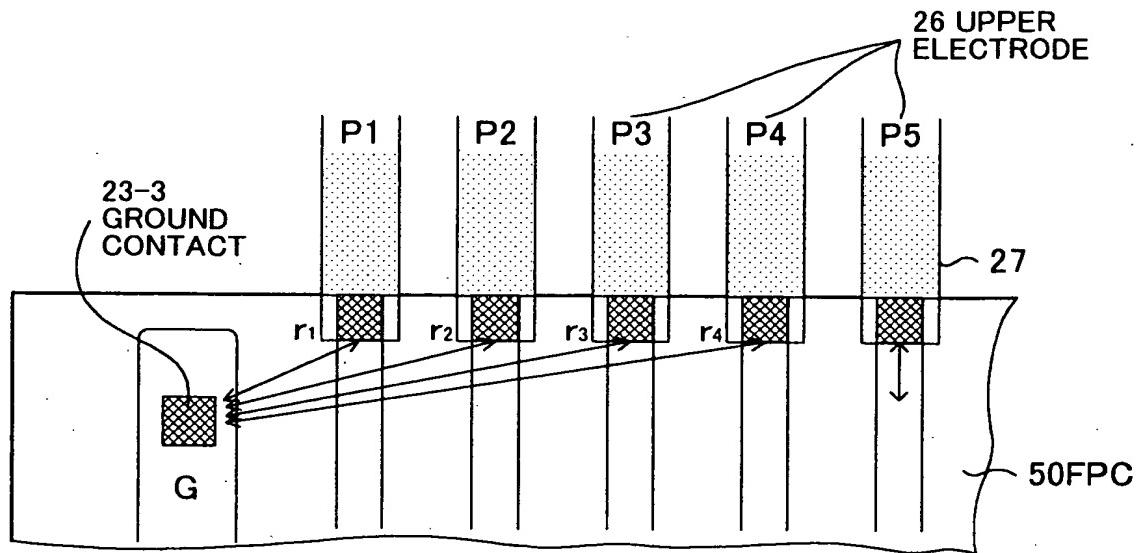
FIG. 1



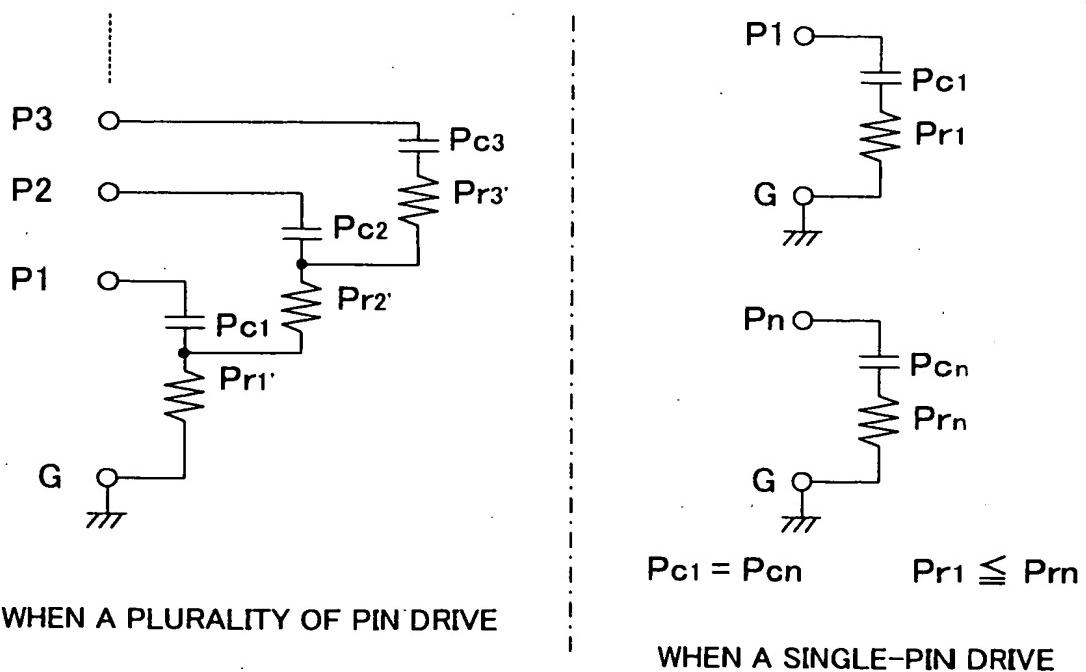
**FIG. 2**



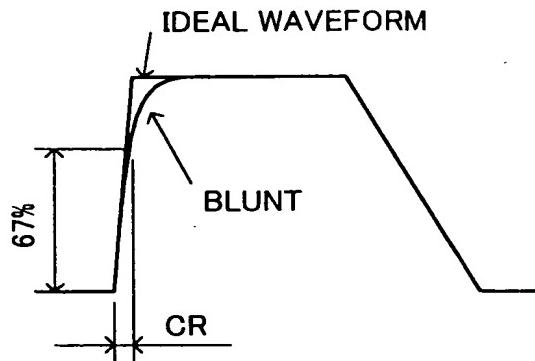
**FIG. 3**



**FIG. 4**



**FIG. 5**



**FIG. 6**

PRESSURE CHAMBER LENGTH $L_c$ (m)	7.00E-04
SIGNAL LINE LENGTH $L_{sig}$	1.00E-04
PIEZO THICKNESS $t_p$ (m)	1.00E-06
PIEZO WIDTH $w_p$ (m)	7.00E-05
VACUUM PERMITTIVITY $\epsilon_0$	8.85E-12
PIEZO SPECIFIC PERMITTIVITY $\epsilon / \epsilon_0$	420
PIEZO CAPACITANCE $C_p$ (pF)	208.152
$C_p = \epsilon * (L_v + L_{sig}) * w_p / t_p$	
RESISTANCE $C_R : \rho (\Omega \cdot m)$	1.27E-07

NOZZLE PITCH (m)	1.70E-04	←DISTANCE FROM BOTH ENDS OF 64 PIN ARRANGEMENT
THE NUMBER OF NOZZLES	64	
COMMON ELECTRODE LENGTH (m)	5.44E-03	
APPLIED VOLTAGE (V)	20	
WAVEFORM RISE TIME (ns)	50	SINGLE PIN DRIVE (pF) 208.152 ALL PIN DRIVE (pF) 13321.7

**FIG. 7**

CrTHICKNESS	0.1	0.2	0.3	0.4	0.5	0.6
RESISTANCE	11.5147	5.75733	3.83822	2.87867	2.30293	1.91911
1-CR	2.4E-09	1.2E-09	8E-10	6E-10	4.8E-10	4E-10
all-CR	1.5E-07	7.7E-08	5.1E-08	3.8E-08	3.1E-08	2.6E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 8

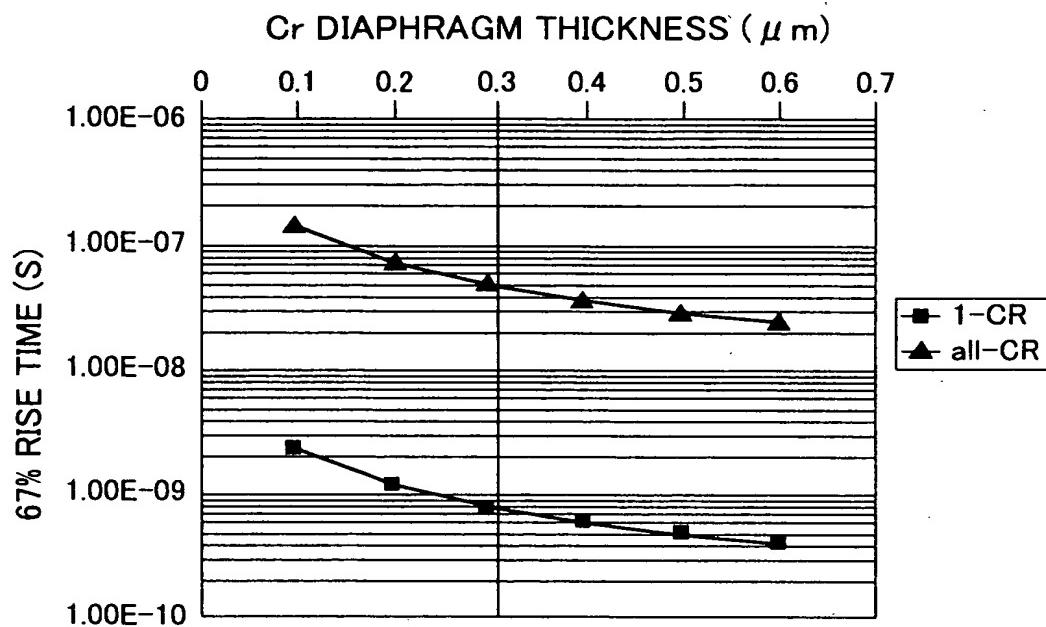


FIG. 9

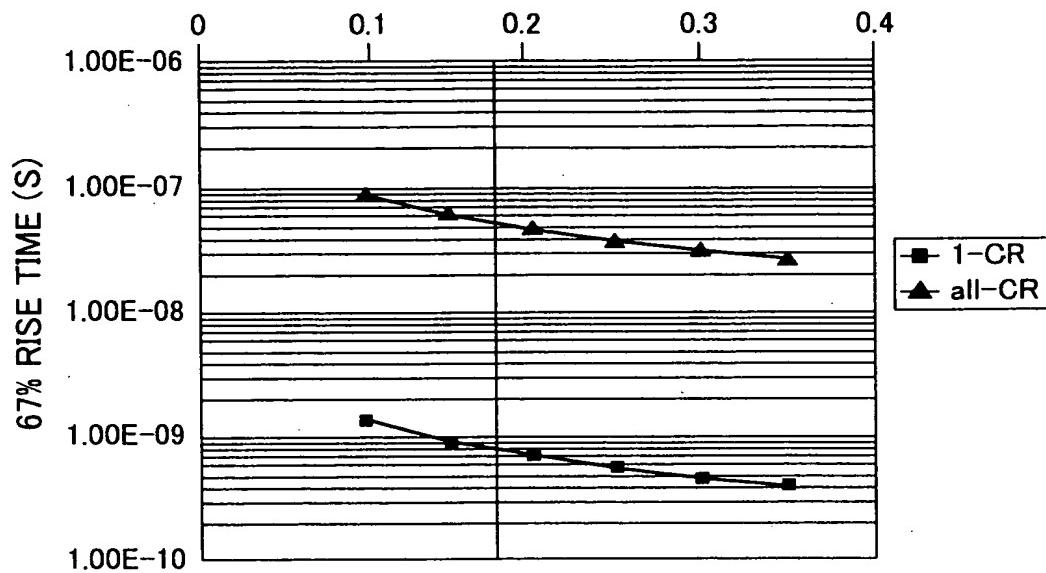
RESISTANCE Ni :  $\rho$  ( $\Omega \cdot \text{m}$ )      7.24E-08

NiTHICKNESS	0.1	0.15	0.2	0.25	0.3	0.35
RESISTANCE	6.56427	4.37618	3.28213	2.26571	2.18809	1.8755
1-CR	1.4E-09	9.1E-10	6.8E-10	5.5E-10	4.6E-10	3.9E-10
all-CR	8.7E-08	5.83E-08	4.37E-08	3.5E-08	2.9E-08	2.5E-08

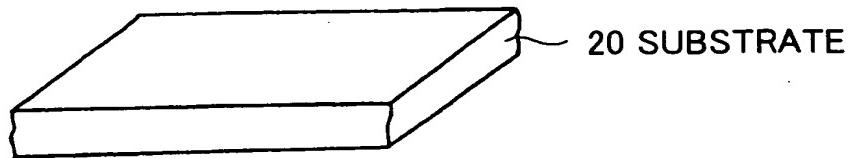
1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

**FIG. 10**

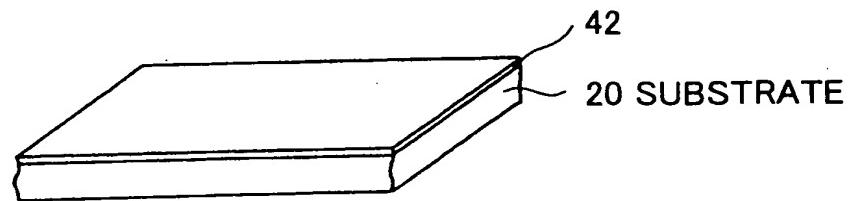
Ni DIAPHRAGM THICKNESS ( $\mu$  m)



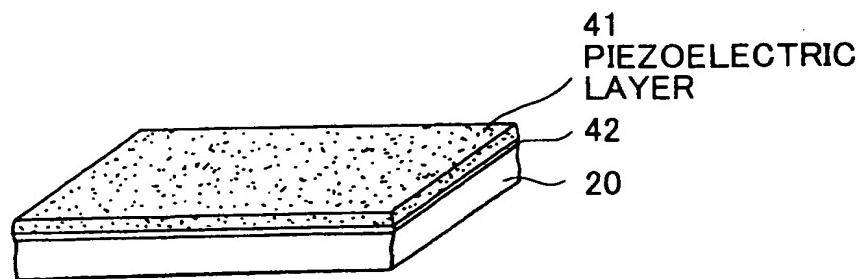
**FIG. 11(A)**



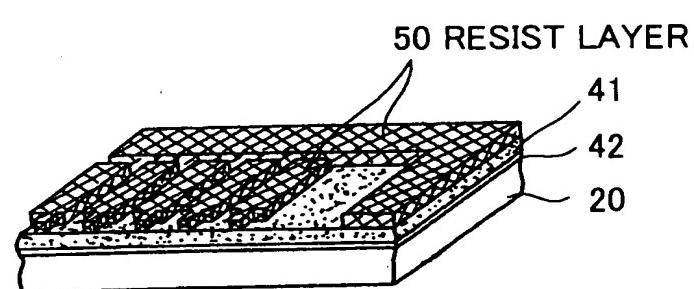
**FIG. 11(B)**



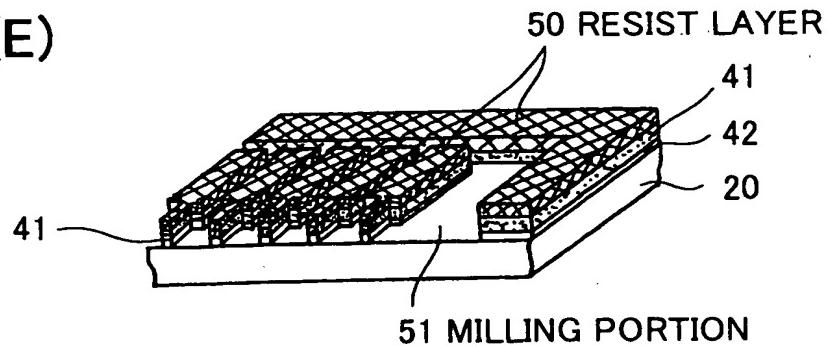
**FIG. 11(C)**



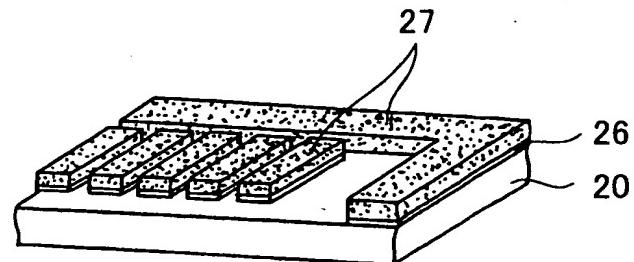
**FIG. 11(D)**



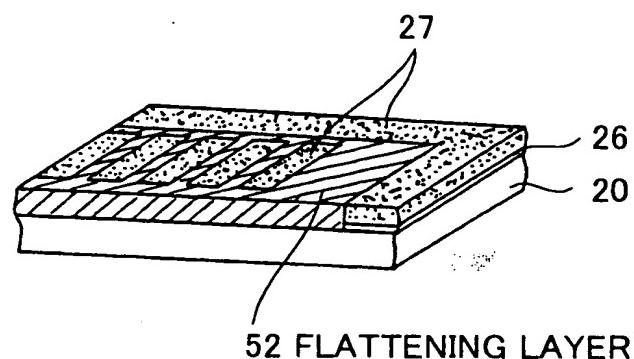
**FIG. 11(E)**



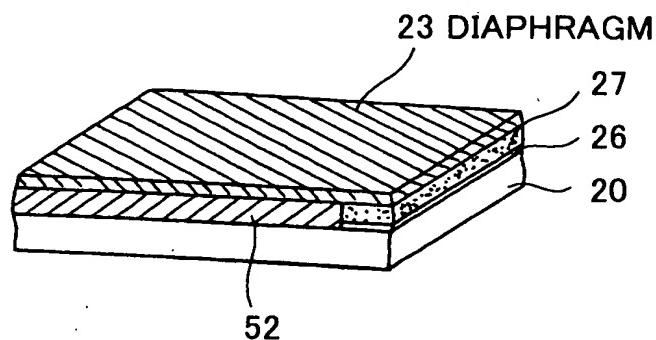
**FIG. 12(F)**



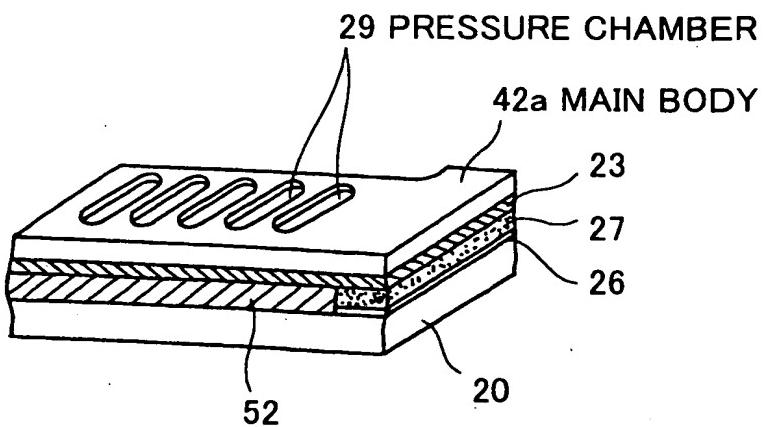
**FIG. 12(G)**



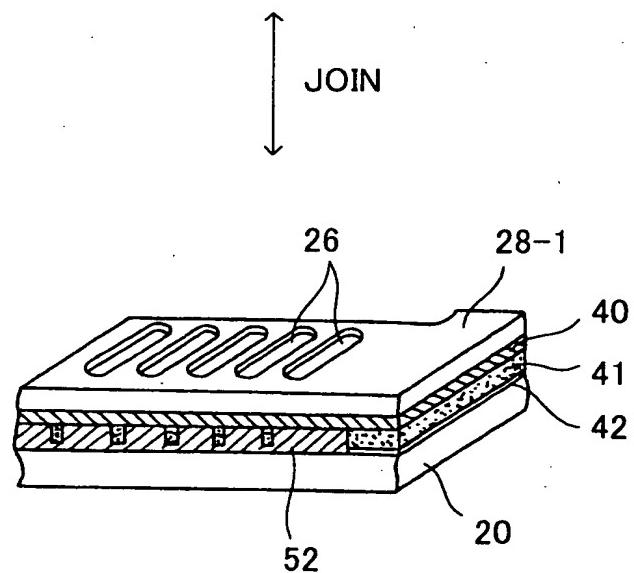
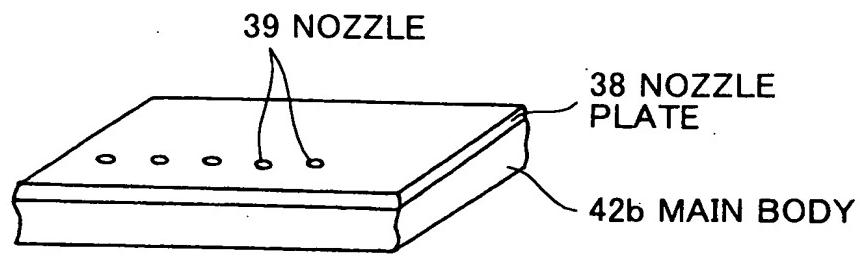
**FIG. 12(H)**



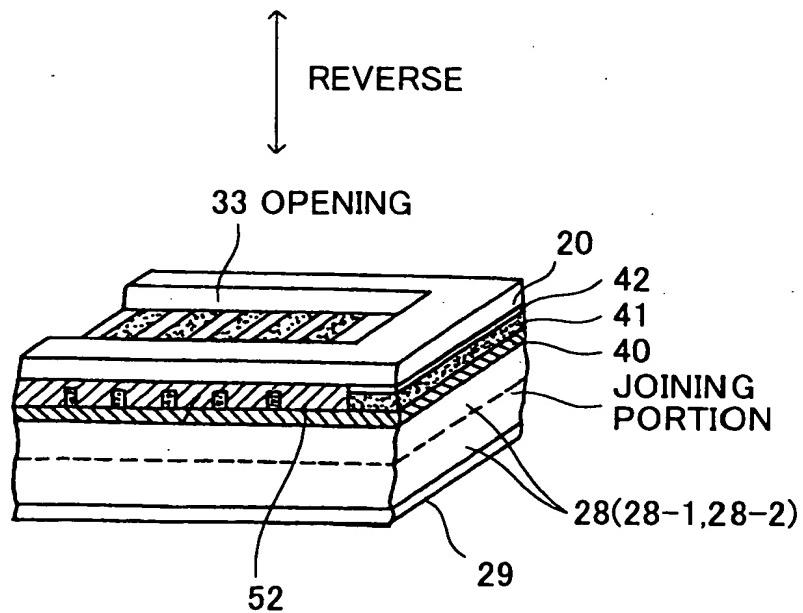
**FIG. 12(I)**



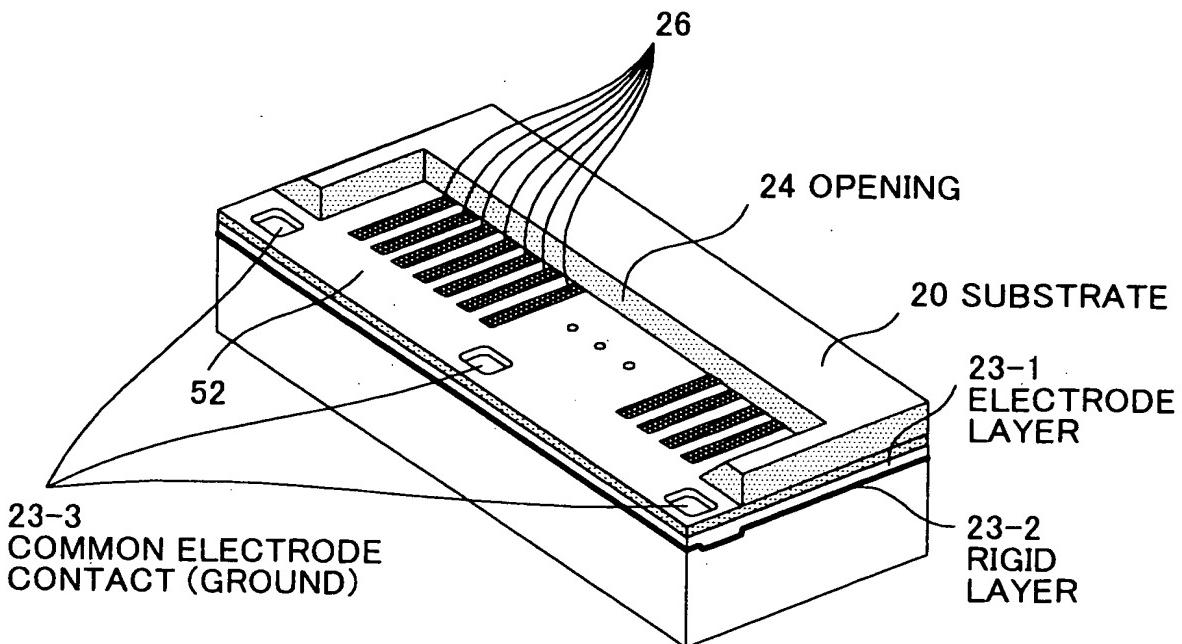
**FIG. 13(J)**



**FIG. 13(K)**



**FIG. 14**



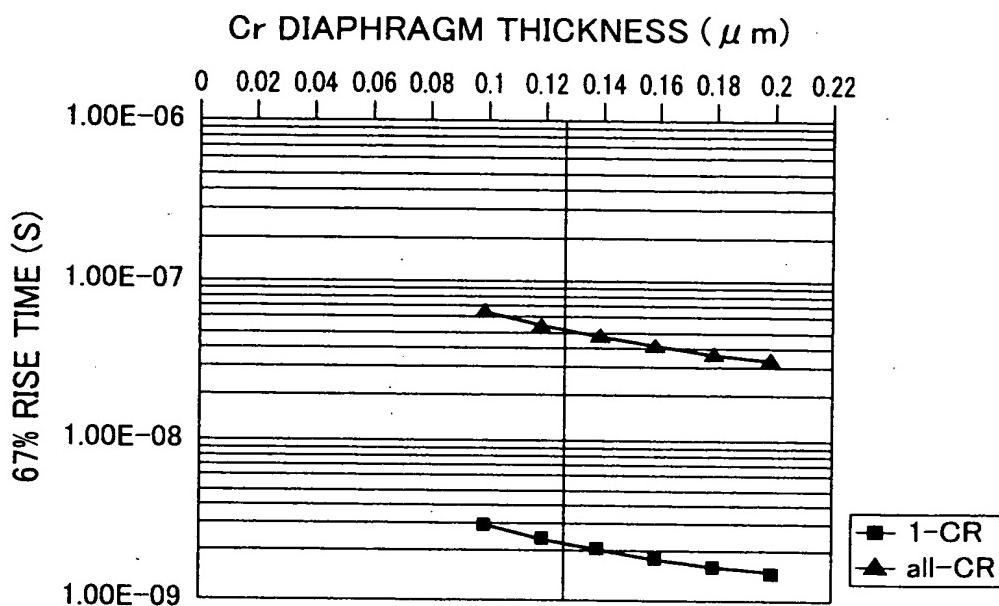
**FIG. 15**

NOZZLE PITCH (m)	1.70E-04		
THE NUMBER OF NOZZLES	21	←THREE POINTS ARE EARTHED AT 64 PIN	
COMMON ELECTRODE LENGTH (m)	1.96E-03	←DISTANCE FROM BLOCK CONTACT	
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	4440.58

CrTHICKNESS	0.1	0.12	0.14	0.16	0.18	0.2
RESISTANCE	14.6596	12.2164	10.4712	9.16228	8.14425	7.32982
1-CR	3.05E-09	2.54E-09	2.18E-09	1.91E-09	1.70E-09	1.53E-09
all-CR	6.51E-08	5.42E-08	4.65E-08	4.07E-08	3.62E-08	3.25E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

**FIG. 16**



**FIG. 17**

RESISTANCE Ni : $\rho$ ( $\Omega \cdot \text{m}$ )	7.24E-08
--	----------

NOZZLE PITCH (m)	1.70E-04	← THREE POINTS ARE EARTHED AT 64 PIN	
THE NUMBER OF NOZZLES	21	← DISTANCE FROM BLOCK CONTACT	
COMMON ELECTRODE LENGTH (m)	1.94E-03	← SINGLE PIN DRIVE (pF)	
APPLIED VOLTAGE (V)	20	208.152	
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	4371.19

NiTHICKNESS	0.02	0.04	0.06	0.08	0.1	0.12
RESISTANCE	41.2289	20.6144	13.743	10.3072	8.24577	6.87148
1-CR	8.58E-09	4.29E-09	2.86E-09	2.15E-09	1.72E-09	1.43E-09
all-CR	1.80E-07	9.01E-08	6.01E-08	4.51E-08	3.60E-08	3.00E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE

all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

**FIG. 18**

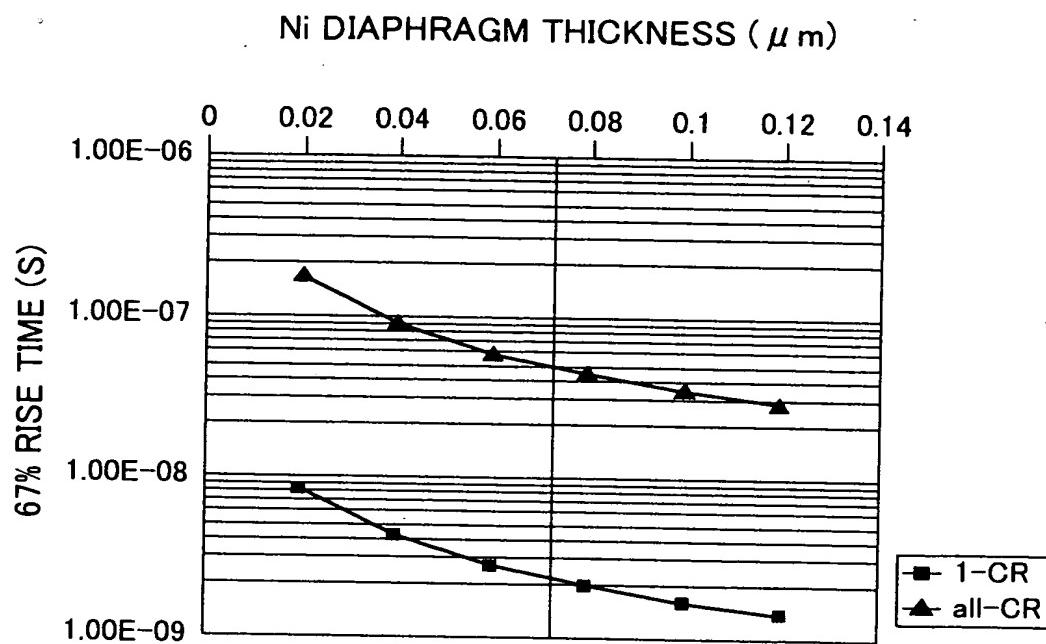


FIG. 19

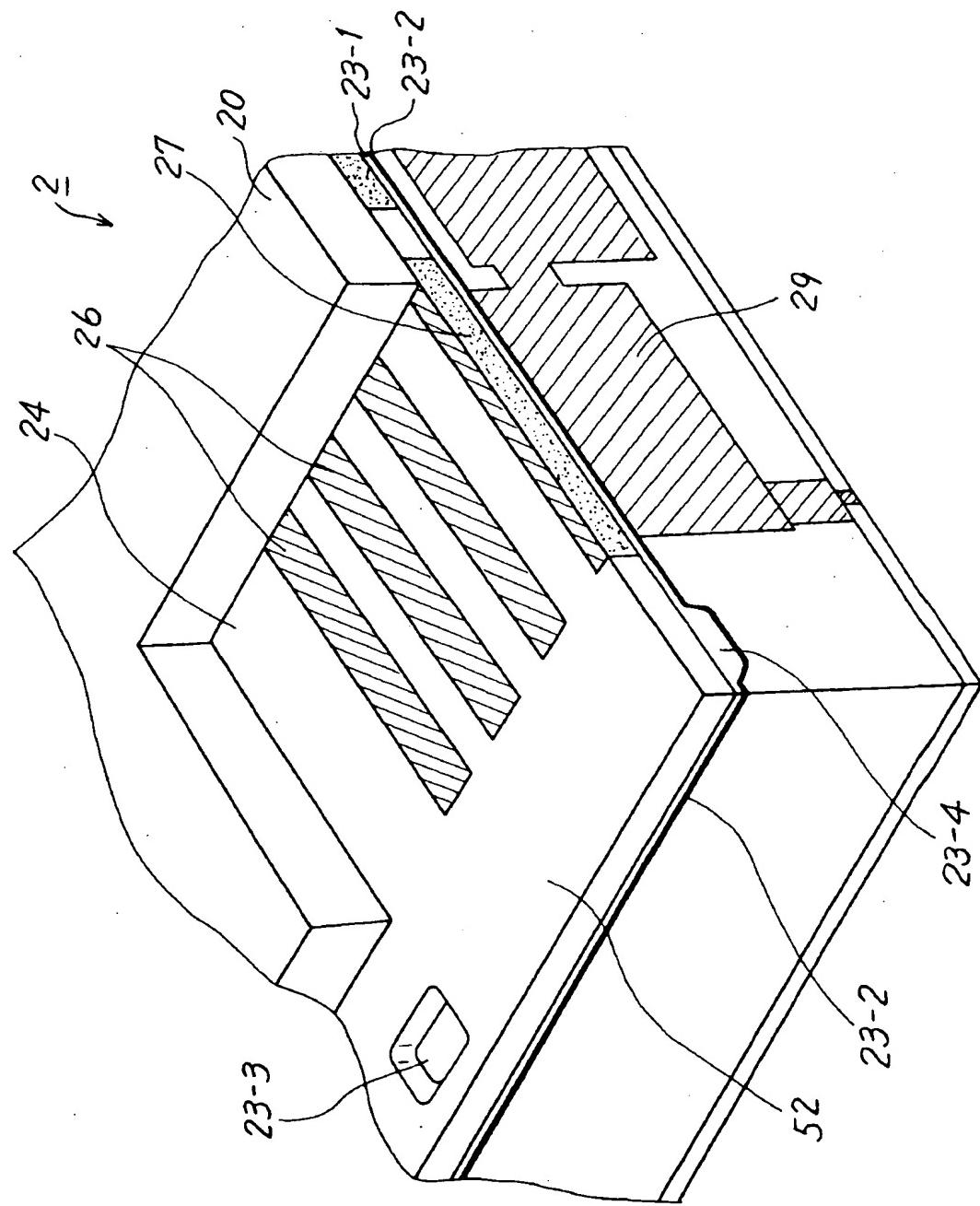
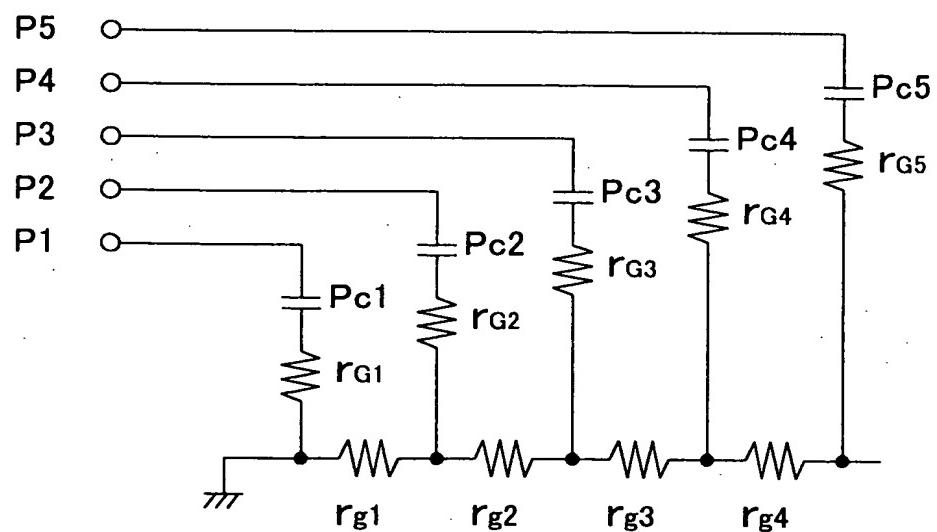
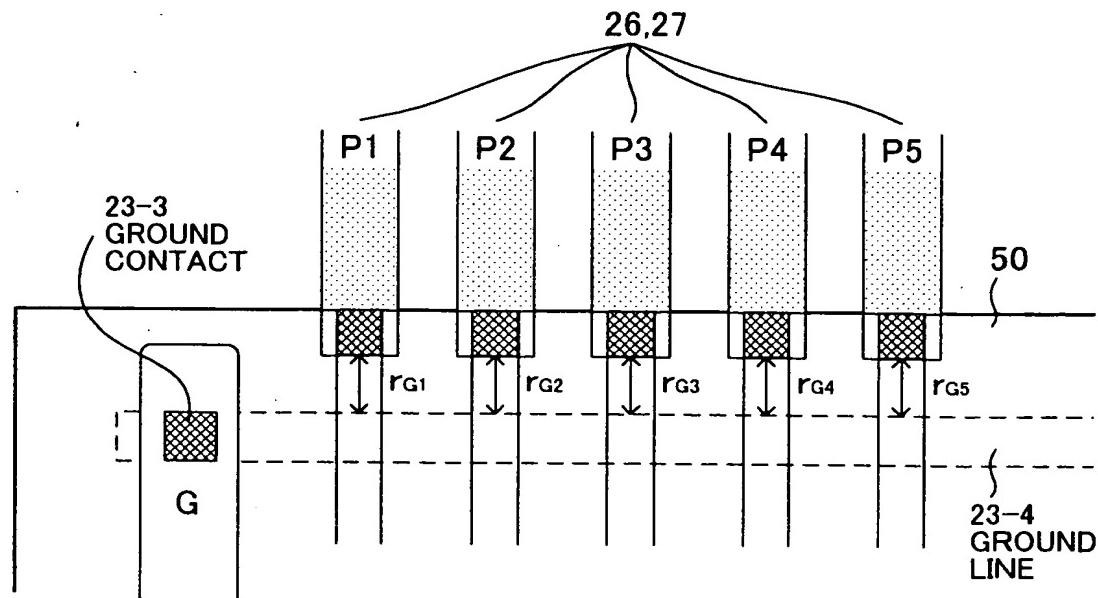


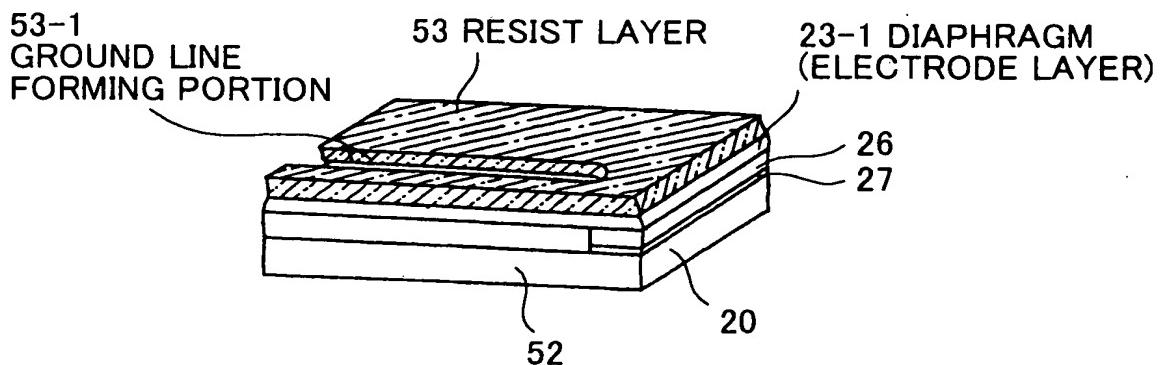
FIG. 20



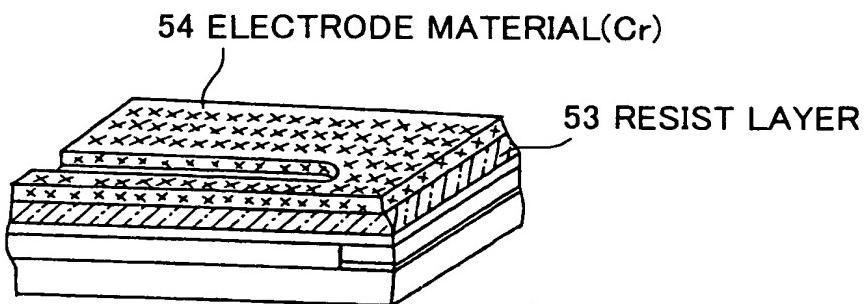
$$Pc_1 = Pc_2 = Pc_3 = Pc_4 = Pc_5$$

$$r_{G1} = r_{G2} = r_{G3} = r_{G4} = r_{G5}$$

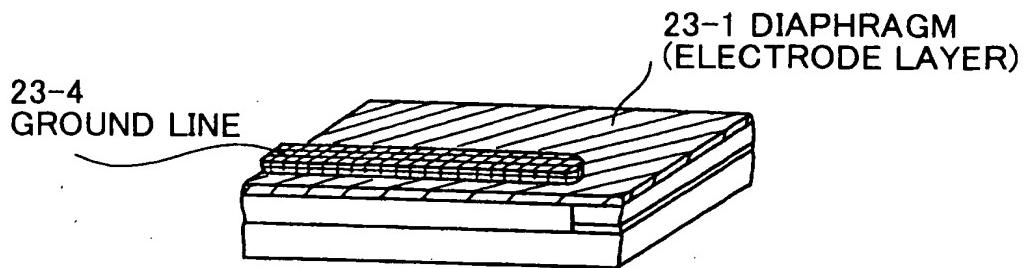
**FIG. 21(L)**



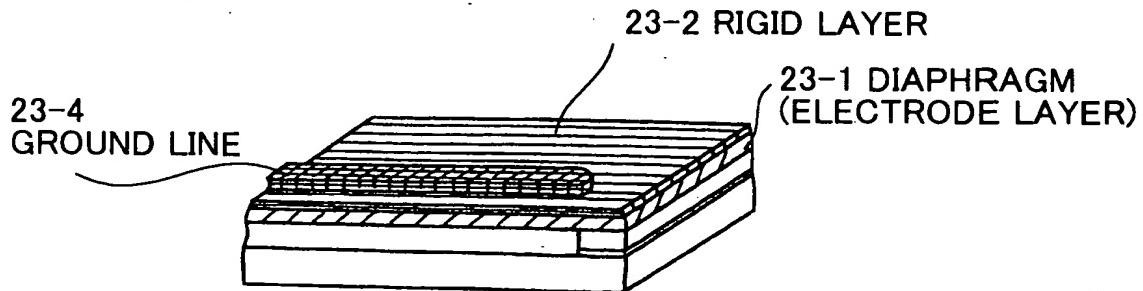
**FIG. 21(M)**



**FIG. 21(N)**



**FIG. 21(O)**



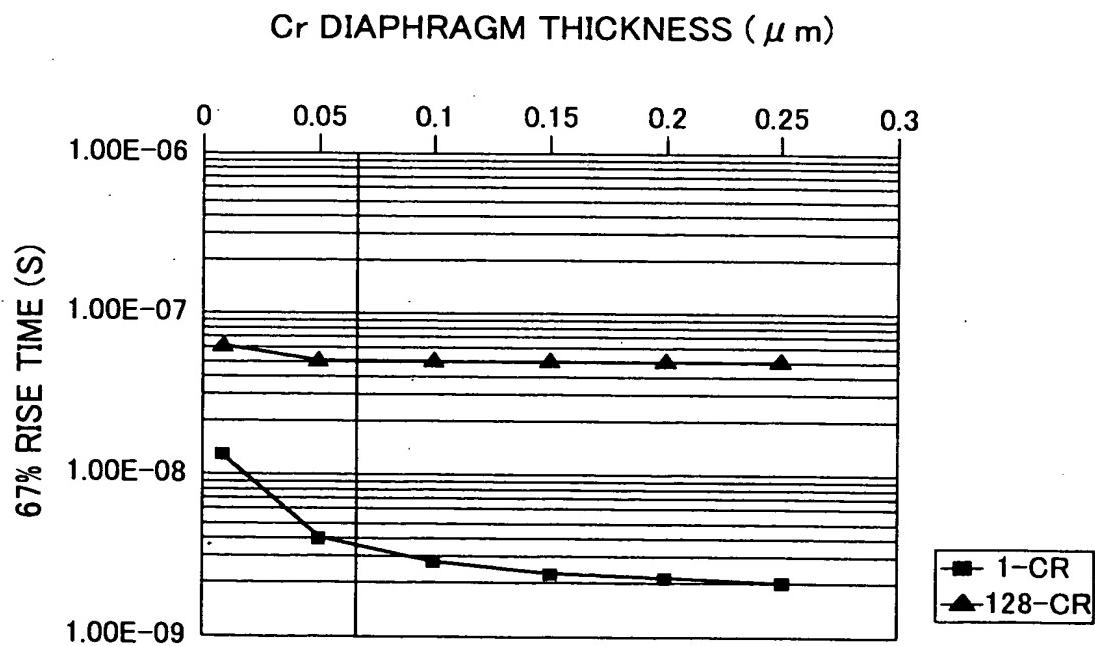
**FIG. 22**

NOZZLE PITCH (m)	1.70E-04	←DISTANCE FROM GROUND LINE TO PZT CENTER
THE NUMBER OF NOZZLES	64	
COMMON ELECTRODE LENGTH (m)	7.50E-04	
GROUND LINE WIDTH (m)	6.00E-05	
GROUND LINE THICKNESS (m)	1.60E-06	
APPLIED VOLTAGE (V)	20	
WAVEFORM RISE TIME (ns)	50	
SINGLE PIN DRIVE (pF)	208.152	
ALL PIN DRIVE (pF)	13321.7	

CrTHICKNESS	0.01	0.05	0.1	0.15	0.2	0.25
1-RESISTANCE	63.2261	18.4025	12.7996	10.932	9.99814	9.43784
1-CR	1.3E-08	3.8E-09	2.7E-09	2.3E-09	2.1E-09	2E-09
128-CR	5.96E-08	5.03E-08	4.91E-08	4.9E-08	4.9E-08	4.8E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
128-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE

**FIG. 23**



**FIG. 24**

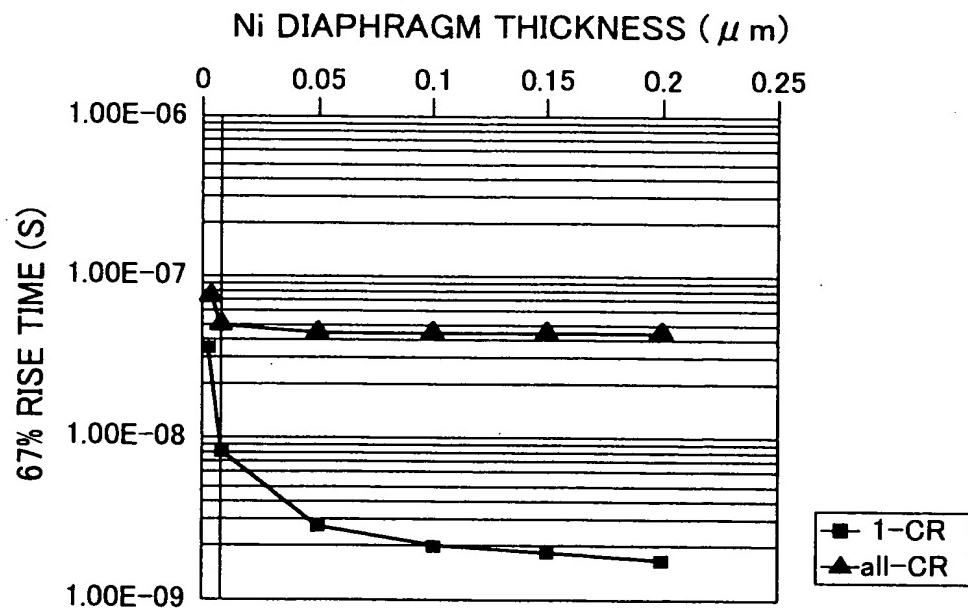
RESISTANCE Ni : $\rho$ ( $\Omega \cdot m$ )	7.24E-08
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NOZZLE PITCH (m)	1.70E-04	<span style="font-size: small;">←DISTANCE FROM GROUND LINE TO PZT CENTER</span>				
THE NUMBER OF NOZZLES	64					
COMMON ELECTRODE LENGTH (m)	7.50E-04					
GROUND LINE WIDTH (m)	6.00E-05					
GROUND LINE THICKNESS (m)	1.00E-06					
APPLIED VOLTAGE (V)	20					
WAVEFORM RISE TIME (ns)	50	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>SINGLE PIN DRIVE (pF)</td> <td>208.152</td> </tr> <tr> <td>ALL PIN DRIVE (pF)</td> <td>13321.7</td> </tr> </table>	SINGLE PIN DRIVE (pF)	208.152	ALL PIN DRIVE (pF)	13321.7
SINGLE PIN DRIVE (pF)	208.152					
ALL PIN DRIVE (pF)	13321.7					

NITHICKNESS	0.002	0.01	0.05	0.1	0.15	0.2
1-RESISTANCE	166.27	38.5054	12.9525	9.75838	8.69368	8.16133
1-CR	3.5E-08	8E-09	2.7E-09	2E-09	1.8E-09	1.7E-09
all-CR	7.70E-08	5.04E-08	4.51E-08	4.4E-08	4.4E-08	4.4E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

**FIG. 25**



## FIG. 26

PRESSURE CHAMBER LENGTH Lc(m)	5.00E-04
SIGNAL LINE LENGTH Lsig	1.00E-04
PIEZo THICKNESS tp(m)	1.00E-06
PIEZo WIDTH wp(m)	4.50E-05

VACUUM PERMITTIVITY $\epsilon_0$	8.85E-12
PIEZo SPECIFIC PERMITTIVITY $\epsilon / \epsilon_0$	420

PIEZo CAPACITANCE Cp(pF)	100.359
$C_p = \epsilon * (L_v + L_{sig}) * w_p / t_p$	

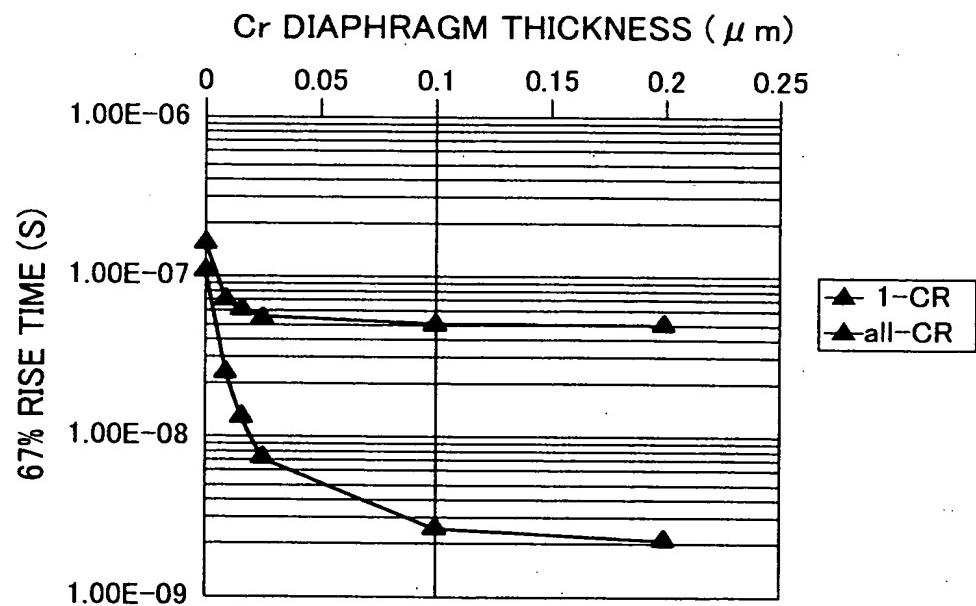
RESISTANCE Cr : $\rho$ ( $\Omega \cdot m$ )	1.27E-07
---	----------

NOZZLE PITCH (m)	8.50E-05	$\longleftrightarrow$ DISTANCE FROM GROUND LINE TO PZT CENTER				
THE NUMBER OF NOZZLES PER SINGLE EARTH	64					
COMMON ELECTRODE LENGTH (m)	7.50E-04					
GROUND LINE WIDTH (m)	2.00E-05					
GROUND LINE THICKNESS (m)	1.10E-06					
APPLIED VOLTAGE (V)	20					
WAVEFORM RISE TIME (ns)	50					
		<table border="1" style="width: 100%;"> <tr> <td>SINGLE PIN DRIVE (pF)</td> <td>100.359</td> </tr> <tr> <td>ALL PIN DRIVE (pF)</td> <td>6422.98</td> </tr> </table>	SINGLE PIN DRIVE (pF)	100.359	ALL PIN DRIVE (pF)	6422.98
SINGLE PIN DRIVE (pF)	100.359					
ALL PIN DRIVE (pF)	6422.98					

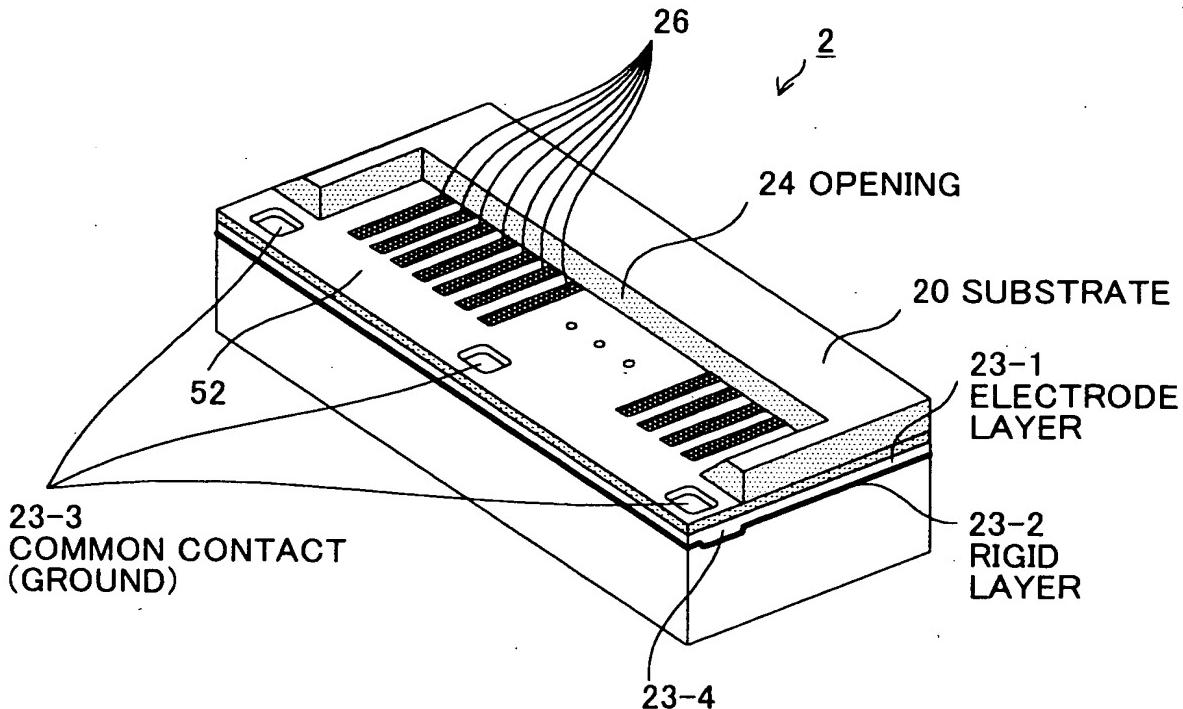
FIG. 27

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	1136.29	239.819	127.761	71.7312	26.9077	21.3048
1-CR	1.1E-07	2.4E-08	1.3E-08	7.2E-09	2.7E-09	2.1E-09
all-CR	1.63E-07	7.29E-08	6.17E-08	5.60E-08	5.2E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE



**FIG. 28**



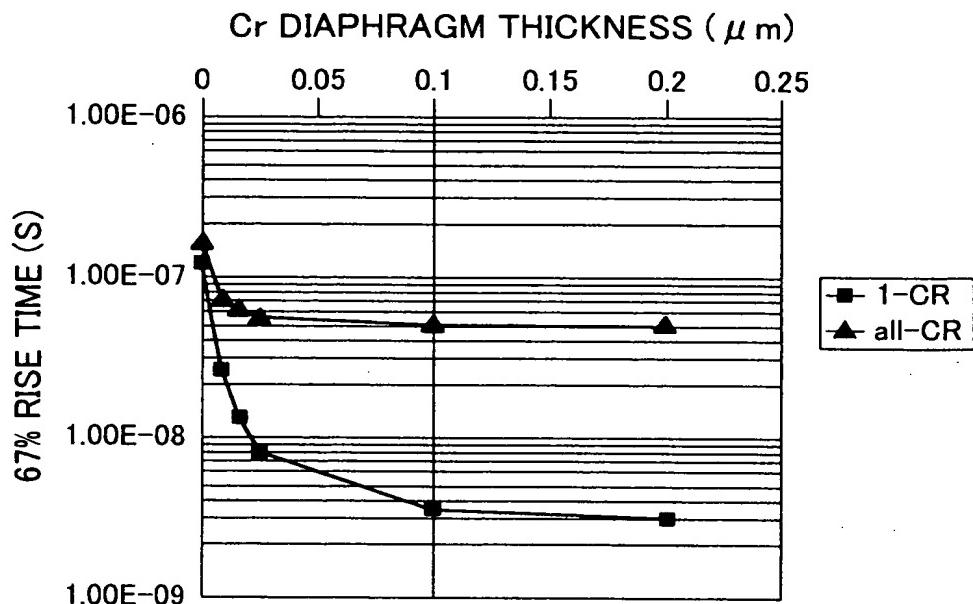
**FIG. 29**

NOZZLE PITCH (m)	1.70E-04	←THREE POINTS ARE EARTHED AT 128 PINS
THE NUMBER OF NOZZLES PER SINGLE EARTH	43	←DISTANCE FROM GROUND LINE TO PZT CENTER
COMMON ELECTRODE LENGTH (m)	7.50E-04	
GROUND LINE WIDTH (m)	2.10E-05	
GROUND LINE THICKNESS (m)	2.00E-06	
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF) 208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF) 8950.54

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	571.346	123.111	67.0814	39.0667	16.655	13.8535
1-CR	1.2E-07	2.6E-08	1.4E-08	8.1E-09	3.5E-09	2.9E-09
all-CR	1.66E-07	7.28E-08	6.11E-08	5.53E-08	5.1E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE

**FIG. 30**



**FIG. 31**

RESISTANCE Ni : $\rho$ ( $\Omega \cdot \text{m}$ )	7.24E-08
--	----------

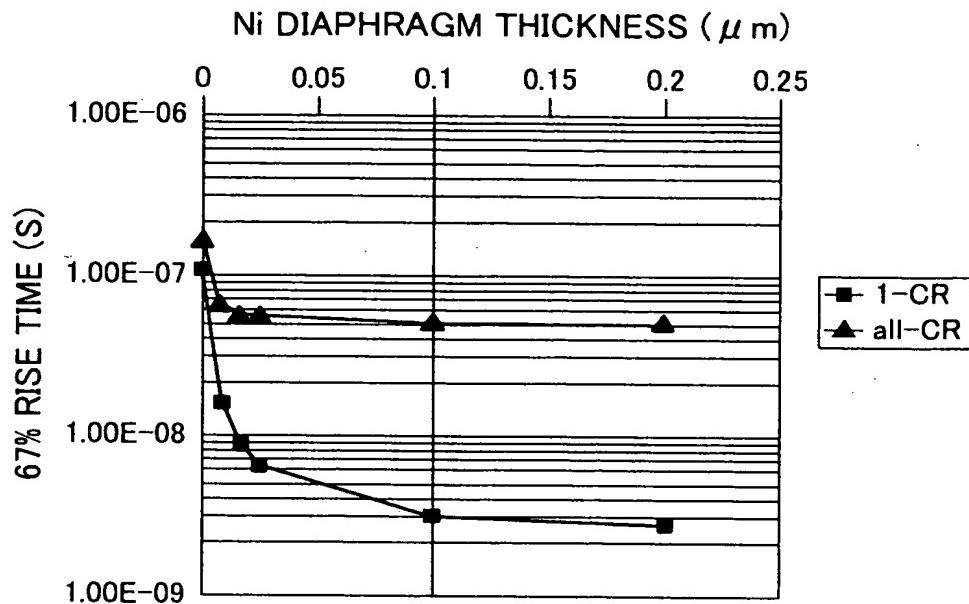
NOZZLE PITCH (m)	1.70E-04		
THE NUMBER OF NOZZLES	43	$\leftarrow$ 128 PINS ARE EARTHED AT THREE POINTS	
COMMON ELECTRODE LENGTH (m)	7.50E-04	$\leftarrow$ DISTANCE FROM GROUND LINE TO PZT CENTER	
GROUND LINE WIDTH (m)	1.20E-05		
GROUND LINE THICKNESS (m)	2.00E-06		
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	8950.54

NiTHICKNESS	0.001	0.005	0.01	0.015	0.1	0.2
1-RESISTANCE	330.438	74.9083	42.9671	32.32	14.22	12.623
1-CR	6.9E-08	1.6E-08	8.9E-09	6.7E-09	3E-09	2.6E-09
all-CR	1.16E-07	6.26E-08	5.60E-08	5.38E-08	5E-08	5E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE

all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

**FIG. 32**



**FIG. 33**

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	1143.8	247.327	135.268	79.2387	34.4151	28.8122
1-CR	1.1E-07	2.5E-08	1.4E-08	8E-09	3.5E-09	2.9E-09
all-CR	1.63E-07	7.26E-08	6.13E-08	5.57E-08	5.1E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE  
all-CR : WAVEFORM RISE TIME WHEN 150 PINS DRIVE

FIG. 34

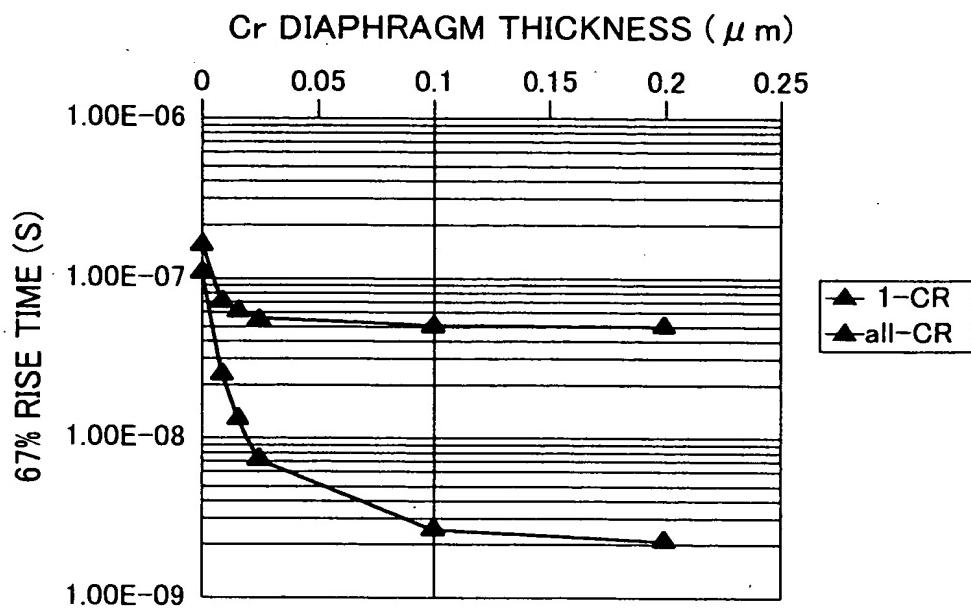


FIG. 35

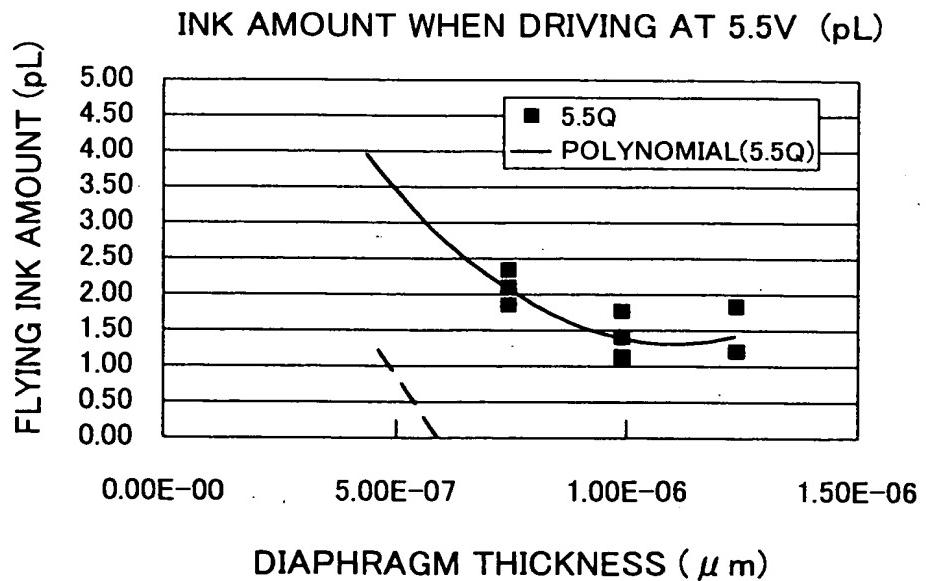


FIG. 36

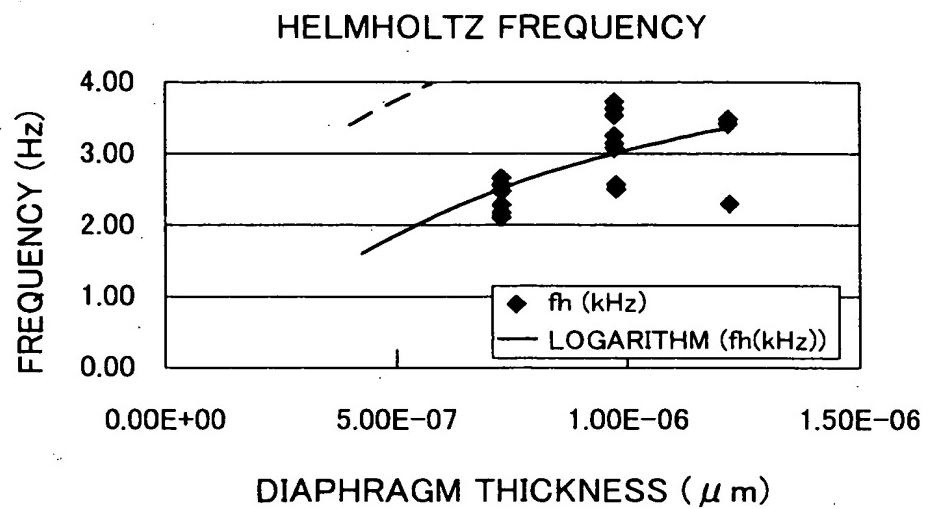


FIG. 37

PRIOR ART

